Data sharing standard for archival and satellite tags

Version 1.2

Feb. 17, 2016

Xavier Hoenner1, Lenore Bajona2, Marta Mihoff2, Jonathan Pye2, Hassan Moustahfid3, Rob Harcourt4

1 Integrated Marine Observing System, University of Tasmania, Private Bag 110, Hobart, TAS 7001, Australia.

2 Ocean Tracking Network (OTN) Biology, Department Dalhousie University, 1355 Oxford Street PO Box 15000 Halifax, NS, Canada, B3H 4R2.

3 NOAA. U.S. Integrated Ocean Observing System, Silver Spring, MD, USA.

4 Department of Biological Sciences, Faculty of Science and Engineering, Macquarie University, Sydney, NSW 2109, Australia.

Table of contents

1. Introduction 2

2. Database schema design 2

2.1 Metadata tables 3

2.2 Data tables 4

3. Discussion 4

4. Database schema: tables and relationships 5

Schema diagram 5

4.1 Metadata tables 6

Device 6

Instrument 8

Surgery 10

Animal release 11

Animal 13

Species 14

Animal measurement 16

Project 17

Data center 19

Users 21

Project role 22

Organisation 23

4.2 Data tables 24

GPS locations 24

Argos locations 25

GLS locations 27

5. References 28

# 1. Introduction

Following the Animal Telemetry Data & Metadata Meeting held in Halifax on July 14 2015 one action item was to develop a data and metadata template for archival and satellite telemetry projects that could be used to share data easily across organizations. The need for such a standard has become obvious due to a growing number of projects (*e.g.* TOPP, POST, AATAMS) collecting important volumes of archival and satellite telemetry data (Kranstauber et al. 2011, Campbell et al. 2015, Dwyer et al. 2015, Campbell et al. 2016), which are more likely to result in the publication of articles in high impact factor journals (Block et al. 2011, Hussey et al. 2015, Kays et al. 2015).

The standard proposed hereafter is primarily based on the metadata convention developed for acoustic telemetry projects (Payne et al. 2013) and the structure of the AATAMS database (AATAMS 2015), with additional metadata information gathered from various projects (*e.g.* OTN, TOPP, Movebank) (Kranstauber et al. 2011). The present convention follows the nomenclature used in Payne et al. (2013) with database fields flagged as ‘required’ or ‘optional’ for users to get a minimum amount of viable information for each dataset. Constraints and relationships between database tables are indicated to highlight how information from different tables can be joined together (Figure 1). For additional database related logic, refer to Payne et al. (2013). The proposed tables were designed using the PostgreSQL database language and the PostGIS extension to convert longitude/latitude coordinates into geometries; these PostgreSQL queries, along with other documents relevant to this standard and sample code to ingest metadata, are publicly available at the following URL: https://github.com/xhoenner/biologging\_data-sharing.

# 2. Database schema design

All metadata, the equivalent ofNetCDF’s global attributes, are stored within 12 different tables detailed below and in Section 4. Metadata for each variable in a dataset, commonly referred to as variable attributes in the NetCDF format, could be easily added in the future if required. The present data exchange standard also includes a database structure to hold animal location data estimated from Argos, Fastloc GPS, and light levels. These animal location datasets are stored in three distinct tables due to additional diagnostic information inherent to each technology.

Detailed field names and meanings for each database table are provided in section 4. Each table has (1) a primary key which constrains some fields to have a unique combination of values, and (2) foreign keys which allow joins between tables so that information from different tables can be extracted in a flat CSV table format.

## 2.1 Metadata tables

1. [**Device**](#_Device_1): information about tags including manufacturer name and model.
2. [**Instrument**](#_Instrument_1): additional information about each tag, *e.g.* firmware/software version, tag configuration, on board sensors.
3. [**Surgery**](#_Surgery_1): specifies which tag was deployed as part of an animal release and how. This is a mapping table between device and animal\_release which allows multiple tag deployments.
4. [**Animal release**](#Animal_release): information about animal capture, release, and potential recovery.
5. [**Animal**](#Animal): information about each animal equipped with tags including sex, species, and age.
6. [**Species**](#_Species_1): Read only table providing a list of species for users to choose from. This list should eventually follow a comprehensive standard approved upon by the tagging community (*e.g.* WoRMS for marine species, <http://www.marinespecies.org/>).
7. [**Animal measurement**](#Animal_measurement): lists all the morphological measurements taken for each tagged animal.
8. [**Project**](#Project): information on tagging projects (*e.g.* abstract, distribution statement), and which data center hosts their data (if any).
9. [**Data center**](#Data_center): name and attributes of each data center.
10. [**User**](#_User_1)**s**: names and contact details of users.
11. [**Project role**](#Project_role): mapping table between the project and users tables.
12. [**Organisation**](#_Organisation_1): information about institutions users belong to.

## 2.2 Data tables

1. [**GPS locations**](#GPS_locations): animal location data and diagnostic information obtained using the Fastloc GPS technology.
2. [**Argos locations**](#Argos_locations): animal location data and diagnostic information obtained using the Argos technology.
3. [**GLS locations**](#GLS_locations): animal location data obtained using light level sensor tags.

# 3. Discussion

To support the relational database tables described above we propose that a web application be developed to provide an interface for users to enter metadata, upload data, and search, filter and download data. Such a web application could re-use the existing infrastructure of the AATAMS graphical user interface (<https://github.com/aodn/aatams/>) that IMOS has set up for the Australian acoustic telemetry community.

We have created a [Github repository](https://github.com/xhoenner/biologging_data-sharing) for people willing to contribute to the present data exchange standard document and underlying PostgreSQL code. GitHub is a web-based Git repository hosting service. It offers revision control and code management functionality along with access control and several collaboration features such as bug tracking, feature requests, task management, and wikis for every project. We suggest that Github be used by people willing to contribute to the data exchange standard by uploading sample data files from different tag manufacturers and models so that progress can be made towards developing a standard format to deliver other data products (*e.g.* CTD profiles, TDR data). An excellent tutorial on Git and Github can be found [here](http://rogerdudler.github.io/git-guide/) and [here](https://guides.github.com/activities/hello-world/).

# 4. Database schema: tables and relationships

### Schema diagram

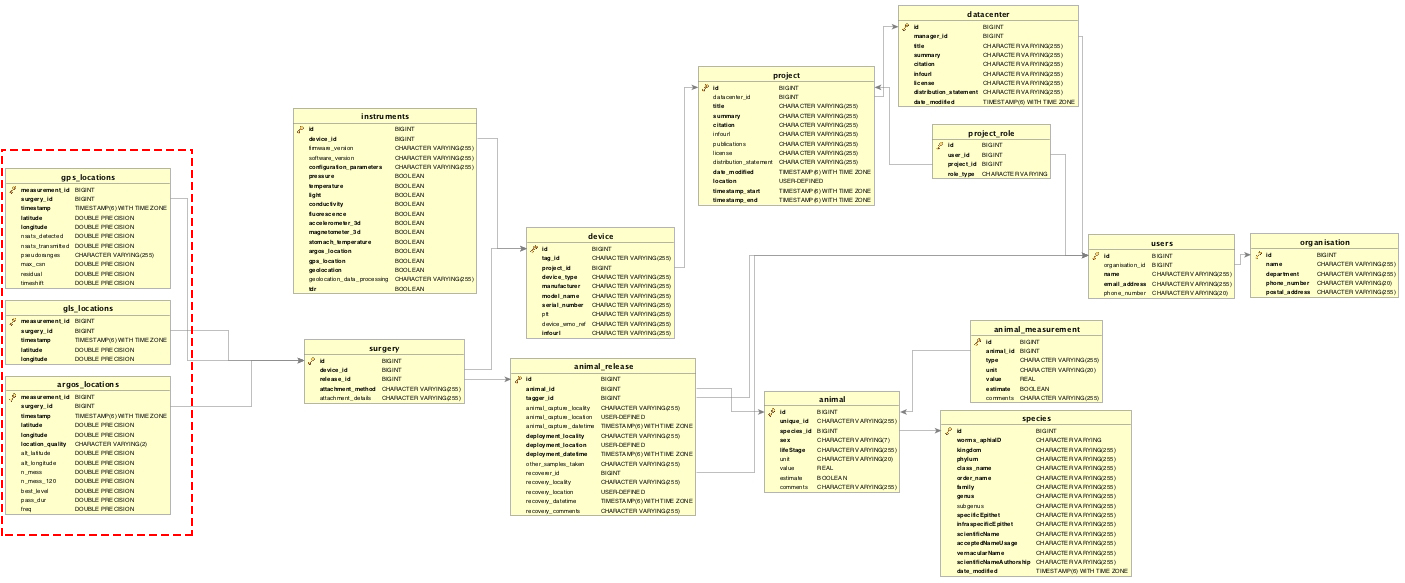


Figure 1: Database schema showing the content of each table and their relationships. Data tables are shown in the red dashed rectangle.

## 4.1 Metadata tables

### Device

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides information about tags including manufacturer name and model.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Device ID (unique). | required | numeric | Primary key |  |
| tag\_id | Tag ID under each project (*e.g.* ct111-030-13) | required | text |  |  |
| project\_id | Project ID. | required | numeric | Foreign key to project table |  |
| device\_type | Type of device (*e.g.* archival, pop-up, satellite). | required | text | Need controlled vocabulary |  |
| manufacturer | Name of manufacturer. | required | text | Need controlled vocabulary |  |
| model\_name | Model name. | required | text | Need controlled vocabulary |  |
| serial\_number | Device serial number. | required | text |  |  |
| ptt | Platform Transmitting Terminal (PTT) number for Argos transmission. | optional | text |  |  |
| device\_wmo\_ref | World Meteorological Organization (WMO) number allocated to this device. | optional | text |  |  |
| infourl | URL to tag model specifications. | required | text |  | ERDDAP |

### Instruments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides additional information about each tag, *e.g.* firmware/software version, tag configuration, on board sensors.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Instrument ID (unique). | required | numeric | Primary key |  |
| device\_id | Device ID. | required | numeric | Foreign key to device table |  |
| firmware\_version | Version number of the firmware used to build the tag. | required | text |  |  |
| software\_version | Version number of the software used for the tag. | required | text |  |  |
| configuration\_parameters | Parameter settings used to configure the tag for deployment; could also provide users with the possibility to upload a text file of specifications. | required | text |  |  |
| pressure | Was pressure data recorded? | required | boolean |  |  |
| temperature | Was temperature data recorded? | required | boolean |  |  |
| light | Was light data recorded? | required | boolean |  |  |
| conductivity | Was conductivity data recorded? | required | boolean |  |  |
| fluorescence | Was fluorescence data recorded? | required | boolean |  |  |
| accelerometer\_3d | Was speed data recorded? | required | boolean |  |  |
| magnetometer\_3d | Was orientation data recorded? | required | boolean |  |  |
| stomach\_temperature | Was stomach temperature data recorded? | required | boolean |  |  |
| argos\_location | Which type(s) of location estimates was provided by the tag? | required | boolean |  |  |
| gps\_location | required | boolean |  |  |
| geolocation | required | boolean |  |  |
| geolocation\_data\_processing | If geolocation = TRUE then specify which algorithm was used to process GLS raw data | optional/required | text |  |  |

### Surgery

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Specifies which tag was deployed as part of an animal release and how.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Surgery ID (unique). | required | numeric | Primary key |  |
| device\_id | Device ID. | required | numeric | Foreign key to device table |  |
| release\_id | Animal release ID. | required | numeric | Foreign key to animal\_release table |  |
| attachment\_method | Describe how the tag was attached (*e.g.* glued, implant). | required | text | Need controlled vocabulary |  |
| attachment\_details | Describe tag attachment (*e.g.* exact location of tag on animal, use of anaesthetics). | optional | text |  |  |

### Animal release

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides information about animal capture, release, and potential recovery.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Tag deployment ID (unique). | required | numeric | Primary key |  |
| animal\_id | Animal ID. | required | numeric | Foreign key to animal table |  |
| tagger\_id | ID of the person who deployed the device on the animal. | required | numeric | Foreign key to users table. |  |
| animal\_capture\_locality | Locality, State/Territory, Country of capture | optional | text |  |  |
| animal\_capture\_location | Longitude and latitude of capture, transformed into a geometry (point). | optional | geometry |  |  |
| animal\_capture\_datetime | Date and time (UTC) of capture. | optional | timestamp |  |  |
| deployment\_locality | Locality, State/Territory, Country of tag deployment | required | text |  |  |
| deployment\_location | Longitude and latitude of tag deployment, transformed into a geometry (point). | required | geometry |  |  |
| deployment\_datetime | Date and time (UTC) of tag deployment. | required | timestamp |  |  |
| deployment\_comments | Describe the deployment event and whether any samples were taken during tag deployment (*e.g.* tissue, blubber, blood). | optional | text |  |  |
| recoverer\_id | ID of the person who recovered the device on the animal | optional | numeric | Foreign key to users table |  |
| recovery\_locality | Locality, State/Territory, Country of recovery | optional | text |  |  |
| recovery\_location | Longitude and latitude of recovery, transformed into a geometry (point). | optional | geometry |  |  |
| recovery\_datetime | Date and time (UTC) of tag recovery. | optional | timestamp |  |  |
| recovery\_comments | Describe the recovery event (*e.g.* damage on tag, biofouling, tag sent back to manufacturer for refurbishing). | optional | text |  |  |

### Animal

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides information about each animal equipped with tags including sex, species, and age.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Animal ID (unique). | required | numeric | Primary key |  |
| unique\_id | Unique ID for each animal *(e.g*. numbered tag, band, transponder*)* | required | text |  |  |
| species\_id | Species ID. | required | numeric | Foreign key to species table |  |
| sex | Sex of animal. | required | text | Can only be female, male, or unknown. | Darwin Core |
| lifeStage | Animal life stage (*e.g.* adult, juvenile, subadult, weaner) | required | text | Need controlled vocabulary | Darwin Core |
| unit | Unit of age (*e.g.* days, months, years) | optional | text | Need controlled vocabulary |  |
| value | Age of animal | optional | numeric |  |  |
| estimate | Is the age value an estimate? | optional | boolean |  |  |
| comments | Additional information on animal (*e.g.* animal origin – wild vs. hatchery, stock, injuries) | optional | text |  |  |

### Species

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Simplified list of species (read only). This list should eventually follow a comprehensive standard approved upon by the tagging community (*e.g.* WoRMS for marine species,** [**http://www.marinespecies.org/**](http://www.marinespecies.org/)**)** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Species ID (unique). | required | numeric | Primary key |  |
| worms\_aphiaID | WoRMS Aphia ID | required | numeric |  |  |
| kingdom | Taxonomical information for each species, see <http://rs.tdwg.org/dwc/terms/index.htm#taxonindex> for more details. | required | text |  | Darwin Core |
| phylum | required | text |  | Darwin Core |
| class\_name | required | text |  |  |
| order\_name | required | text |  |  |
| family | required | text |  | Darwin Core |
| genus | required | text |  | Darwin Core |
| subgenus | optional | text |  | Darwin Core |
| specificEpithet | required | text |  | Darwin Core |
| infraspecificEpithet | required | text |  | Darwin Core |
| scientificName | required | text |  | Darwin Core |
| acceptedNameUsage | required | text |  | Darwin Core |
| vernacularName | required | text |  | Darwin Core |
| scientificNameAuthorship | Recognised authority (author and date) for each species name, and source of this information. | required | text |  | Darwin Core |
| date\_modified | Date on which each species entry was last modified. | required | timestamp |  | NACDD |

### Animal measurement

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Lists all the morphological measurements taken for each tagged animal.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Animal measurement ID (unique). | required | numeric | Primary key |  |
| animal\_id | Animal ID. | required | numeric | Foreign key to animal table |  |
| type | Type of measurement (*e.g.* length, weight, total length, carapace length, carapace width, fork length, width). | required | text | Need controlled vocabulary |  |
| unit | Unit of measurement (*e.g.* mm, cm, m, g, kg). | required | text | Need controlled vocabulary |  |
| value | Measurement value. | required | text |  |  |
| estimate | Is the measurement value an estimate? | required | boolean |  |  |
| comments | Additional information on each measurement. | optional | text |  |  |

### Project

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides information on tagging projects, which data center hosts data, who is the principal investigator.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Project ID (unique). | required | numeric | Primary key |  |
| datacenter\_id | ID of data center. Not a compulsory so that people who would like to contribute can do so without having their data in a data centre. | optional | numeric | Foreign key to datacenter table |  |
| title | Project name | required | text |  | NACDD |
| summary | Description of project including background, methods, and objectives. | required | text |  | NACDD |
| citation | Citation to be used in publications using the data from the project should follow the following format: “ProjectName. [year-of-data-download], [Title], [Data access URL], accessed [date-of-access]”. | required | text |  |  |
| infourl | URL to project information website or metadata record. | optional | text |  | ERDDAP |
| publications | Published or web-based references that describe the data or methods used to produce the data from the project. Multiple references should be separated with a semicolon. If available DOIs should be given. | optional | text |  |  |
| license | Describe the project restrictions to data access and distribution. | optional | text |  | NACDD |
| distribution\_statement | Statement describing data distribution policy (*e.g.* ‘You accept all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from using the data from this project’). | optional | text |  |  |
| date\_modified | Date on which the project data was last modified. | required | timestamp |  | NACDD |
| location | Min and max longitude and latitude of the project data, transformed into a geometry (polygon). | required | geometry |  |  |
| timestamp\_start | Start date and time (UTC) of the project data. | required | timestamp |  |  |
| timestamp\_end | End date and time (UTC) of the project data. | required | timestamp |  |  |

### Data center

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides name and attributes of each data center.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Data center ID (unique). | required | numeric | Primary key |  |
| manager\_id | ID of manager of data center. | required | numeric | Foreign key to users table |  |
| title | Data center name | required | text |  | NACDD |
| summary | Description of data center including background, methods, and objectives. | required | text |  | NACDD |
| citation | Citation to be used in publications using the data from the data center should follow the following format: “DataCenterName. [year-of-data-download], [Title], [Data access URL], accessed [date-of-access]”. | required | text |  |  |
| infourl | URL to data center information website or metadata record. | required | text |  | ERDDAP |
| license | Describe the data center restrictions to data access and distribution. | optional | text |  | NACDD |
| distribution\_statement | Statement describing data distribution policy (*e.g.* ‘You accept all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from using the data from this project’). | optional | text |  |  |
| date\_modified | Date on which the data center data was last modified. | required | timestamp |  | NACDD |

### Users

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides names and contact details of users.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | User ID. | required | numeric | Primary key |  |
| organisation\_id | ID of organisation each user belongs to. | required | numeric | Foreign key to organisation table. |  |
| name | Name of user | required | text | Should be unique. |  |
| email\_address | Email address of user | required | text |  |
| phone\_number | Phone number of user, including country and area code. | optional | text |  |  |

### Project role

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides mapping between the project and users table.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Project role ID. | required | numeric | Primary key |  |
| user\_id | User ID. | required | numeric | Foreign key to users table. |  |
| project\_id | Project ID. | required | numeric | Foreign key to project table. |  |
| role\_type | Role of user in project (*e.g.* Principal Investigator, Co-Investigator, Administrator, Student). | required | text | Need controlled vocabulary |  |

### Organisation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides information about institutions users belong to.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| id | Organisation ID. | required | numeric | Primary key |  |
| name | Name of organisation | required | text |  |  |
| department | Department name within organisation | required | text |  |  |
| phone\_number | Phone number of organisation, including country and area code. | required | text |  |  |
| postal\_address | Postal address of organisation | required | text |  |  |

## 4.2 Data tables

### GPS locations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides animal location data and diagnostic information obtained using the Fastloc GPS technology.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| measurement\_id | Measurement ID (unique). | required | numeric | Primary key |  |
| surgery\_id | Surgery ID linked to each dataset | required | numeric | Foreign key to surgery table |  |
| timestamp | Time assigned to the location (UTC) in the following format "YYYY-MM-DD hh:mm:ss" | required | timestamp |  |  |
| latitude | In decimal format and degree North. | required | numeric | -90 < lat < 90 | CF |
| longitude | In decimal format and degree East. | required | numeric | -180 < lon < 180 | CF |
| nsats\_detected | Diagnostic information for each timestamp, longitude, latitude combination. Need to confirm the usefulness and meaning of each of these fields. | optional | numeric | Need controlled vocabulary |  |
| nsats\_transmitted | optional | numeric |  |  |
| pseudoranges | optional | text |  |  |
| max\_csn | optional | numeric |  |  |
| residual | optional | numeric |  |  |
| timeshift | optional | numeric |  |  |

### Argos locations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides animal location data and diagnostic information obtained using the Argos technology. Need to discuss whether diagnostic fields are useful.** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| measurement\_id | Measurement ID (unique). | required | numeric | Primary key |  |
| surgery\_id | Surgery ID linked to each dataset | required | numeric | Foreign key to surgery table |  |
| timestamp | Time assigned to the location (UTC) in the following format "YYYY-MM-DD hh:mm:ss" | required | timestamp |  |  |
| latitude | Preferred longitude estimate (WGS 84 datum), in decimal format and degree North. | required | numeric | -90 < lat < 90 | CF |
| longitude | Preferred latitude estimate (WGS 84 datum), in decimal format and degree East. | required | numeric | -180 < lon < 180 | CF |
| location\_quality | Location Quality assigned by Argos (-1 = class A, -2 = class B, 9 = class Z). | required | text | Need controlled vocabulary |  |
| alt\_latitude | Alternative solution to position equations, in decimal format and degree North. | optional | numeric |  |  |
| alt\_longitude | Alternative solution to position equations, in decimal format and degree East. | optional | numeric |  |  |
| n\_mess | Number of uplinks received during the satellite pass. | optional | numeric |  |  |
| n\_mess\_120 | Number of uplinks received with signal strength > -120 dB. | optional | numeric |  |  |
| best\_level | Signal strength of strongest uplink (dB). | optional | numeric |  |  |
| pass\_dur | Duration of satellite overpass (seconds). | optional | numeric |  |  |
| freq | Measured frequency of SRDL signal at the satellite (Hz). | optional | numeric |  |  |

### GLS locations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Provides animal location data obtained using light level sensor tags** | | | | | |
|  | | | | | |
| *Field name* | *Description* | *Required* | *Data type* | *Constraints* | *Authority* |
| measurement\_id | Measurement ID (unique). | required | numeric | Primary key |  |
| surgery\_id | Surgery ID linked to each dataset | required | numeric | Foreign key to surgery table |  |
| timestamp | Time assigned to the location (UTC) in the following format "YYYY-MM-DD hh:mm:ss" | required | timestamp |  |  |
| latitude | In decimal format and degree North. | required | numeric | -90 < lat < 90 | CF |
| longitude | In decimal format and degree East. | required | numeric | -180 < lon < 180 | CF |

# 5. References

AATAMS (2015) The Australian Animal Tracking and Monitoring System (AATAMS) National Database Web Application. Accessed 11 November 2015. https://aatams.emii.org.au/aatams

Block BA, Jonsen ID, Jorgensen SJ, Winship AJ, Shaffer SA, Bograd SJ, Hazen EL, Foley DG, Breed GA, Harrison AL, Ganong JE, Swithenbank A, Castleton M, Dewar H, Mate BR, Shillinger GL, Schaefer KM, Benson SR, Weise MJ, Henry RW, Costa DP (2011) Tracking apex marine predator movements in a dynamic ocean. Nature 475:86-90

Campbell HA, Beyer HL, Dennis TE, Dwyer RG, Forester JD, Fukuda Y, Lynch C, Hindell MA, Menke N, Morales JM, Richardson C, Rodgers E, Taylor G, Watts ME, Westcott DA (2015) Finding our way: On the sharing and reuse of animal telemetry data in Australasia. Science of The Total Environment 534:79-84

Campbell HA, Urbano F, Davidson S, Dettki H, Cagnacci F (2016) A plea for standards in reporting data collected by animal-borne electronic devices. Animal Biotelemetry 4:1-4

Dwyer RG, Brooking C, Brimblecombe W, Campbell HA, Hunter J, Watts M, Franklin CE (2015) An open Web-based system for the analysis and sharing of animal tracking data. Animal Biotelemetry 3:1-11

Hussey NE, Kessel ST, Aarestrup K, Cooke SJ, Cowley PD, Fisk AT, Harcourt RG, Holland KN, Iverson SJ, Kocik JF, Mills Flemming JE, Whoriskey FG (2015) Aquatic animal telemetry: A panoramic window into the underwater world. Science 348

Kays R, Crofoot MC, Jetz W, Wikelski M (2015) Terrestrial animal tracking as an eye on life and planet. Science 348

Kranstauber B, Cameron A, Weinzerl R, Fountain T, Tilak S, Wikelski M, Kays R (2011) The Movebank data model for animal tracking. Environmental Modelling & Software 26:834-835

Payne J, Moustahfid H, Mayorga E, Branton R, Mihoff M, Bajona L (2013) A metadata convention for animal acoustic telemetry data. [http://ioostech.googlecode.com/files/AAT Metadata Convention v1.2.pdf](http://ioostech.googlecode.com/files/AAT%20Metadata%20Convention%20v1.2.pdf)